



# **Earth Remote Sensing Technologies in the Twenty-First Century**

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## **Systems, Models, Sensorwebs**

- The Earth is a complex system, or system of systems.
- An Earth System Model can bring many benefits through prediction of hazards to human life.
- This model will depend on improved observing systems.
- Ultimately, a sensorweb will be in place to provide more accurate and more frequent inputs to the Earth System Model.

# Observing System of the Future

- **Advanced Sensors**

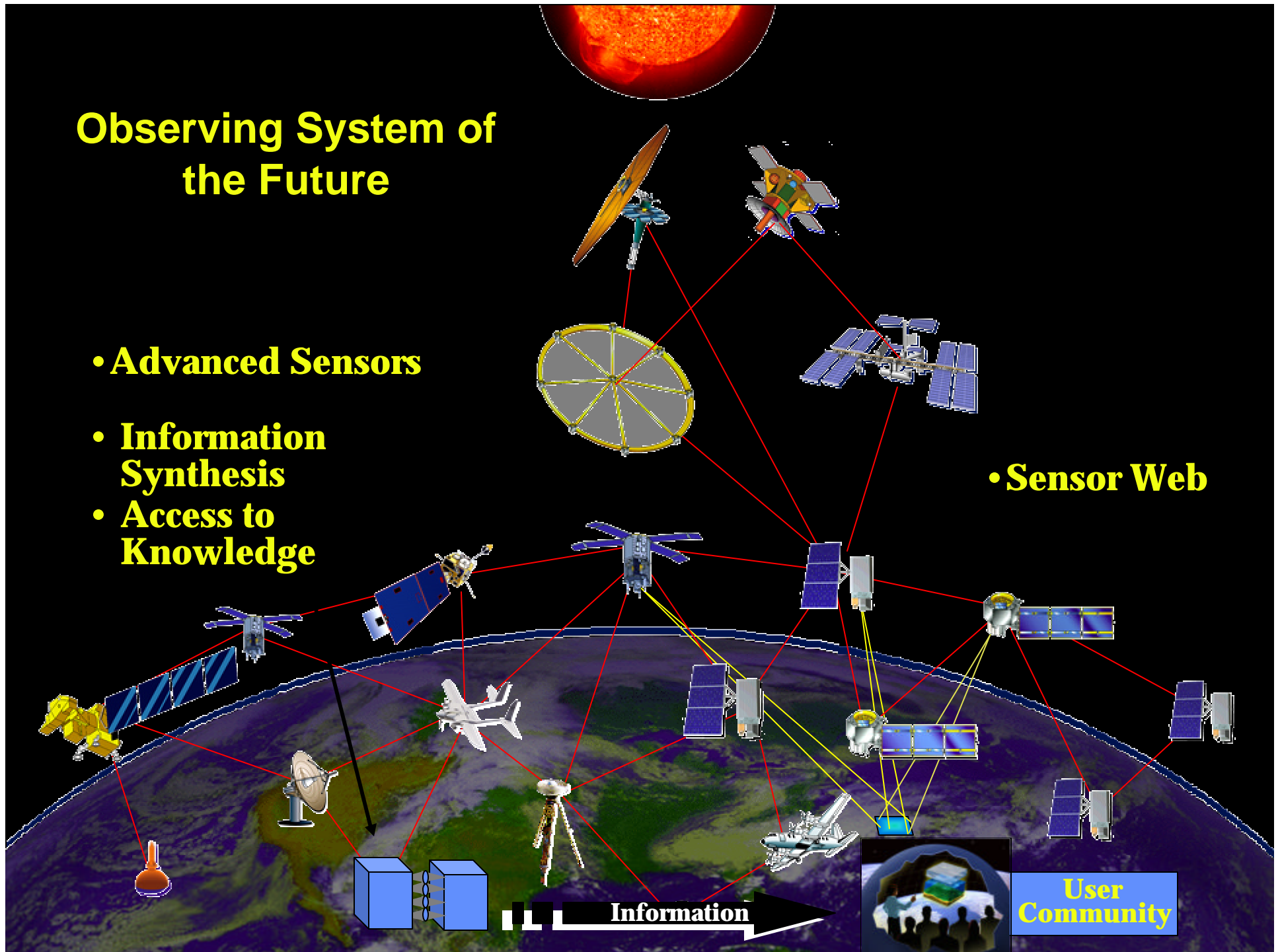
- **Information Synthesis**

- **Access to Knowledge**

- **Sensor Web**

**Information**

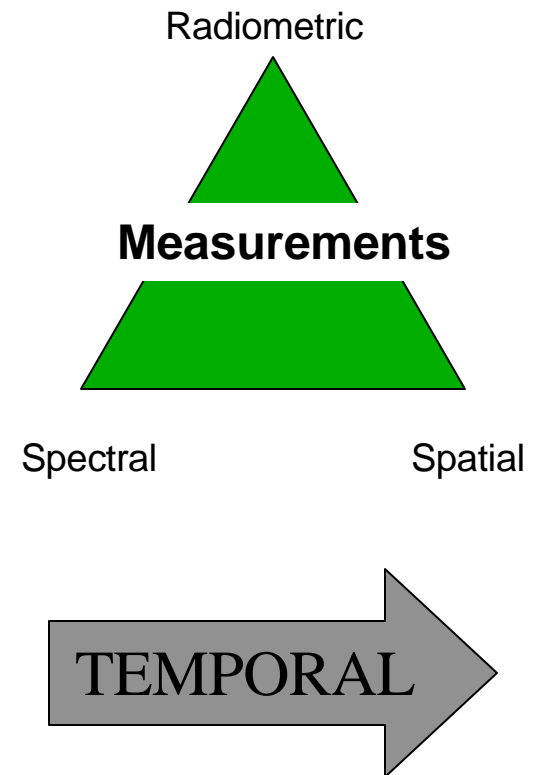
**User Community**





## Remote Sensing Evolution

- Continuous improvements in spatial, spectral, radiometric, and temporal characteristics of measurements will be needed.
- Examples include:
  - Improved spatial and temporal resolution for soil moisture measurements in LEO.
  - Improved temporal resolution by moving atmospheric chemistry measurements to GEO and L2.
  - Increased spectral bandwidth, resolution, and coverage for hyperspectral measurements of vegetation, ocean color, and minerals.



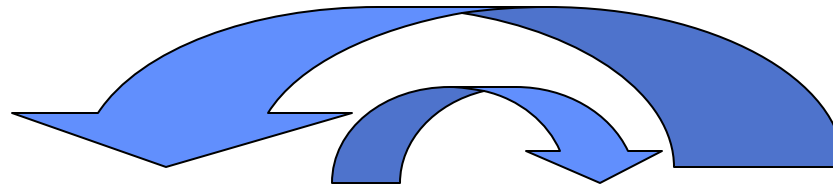


# New Technology Trends

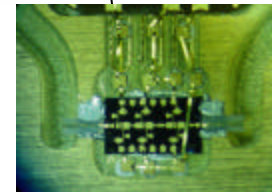
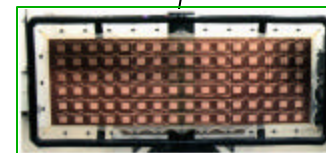
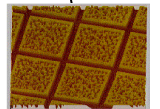
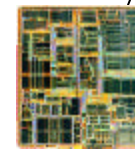
## THEMES

- Miniaturization of electronics
- High-performance onboard computing
- Large, lightweight structures
- Increased power active sensing
- Compact optics
- Frequency flexibility

NEW MATERIALS



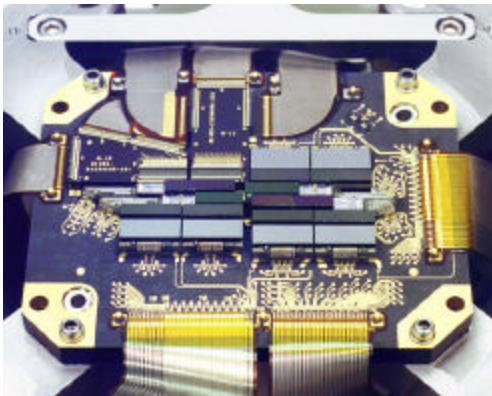
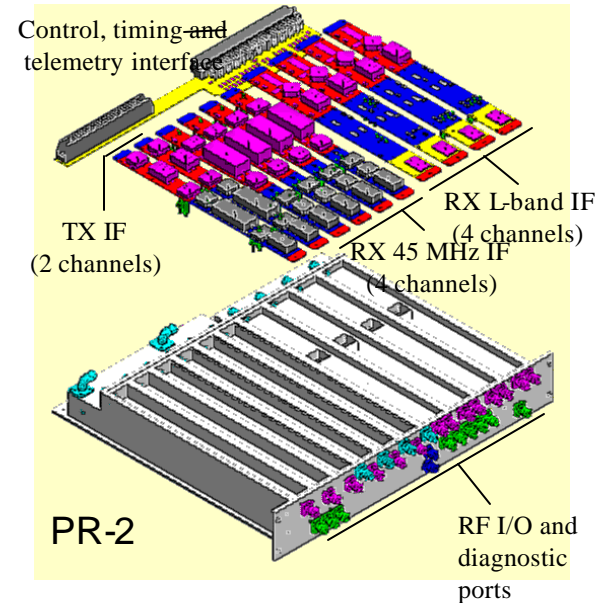
## Earth Science Technology Office ESTO



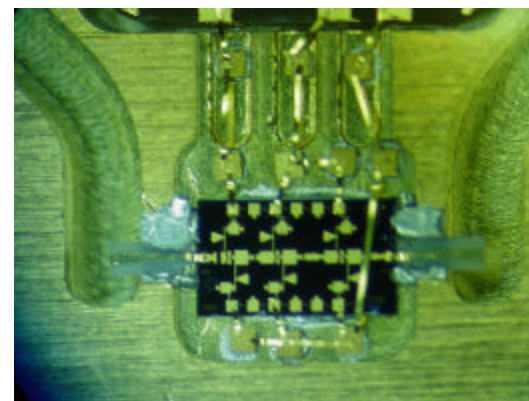


## Miniaturization of Electronics

- Increased integration
- Reduced feature size
- 3-Dimensional packaging
- Integration with S/C structure
- Digital and RF circuits



VLWIR PV Detectors

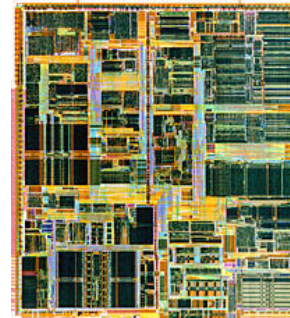


MMIC LNA

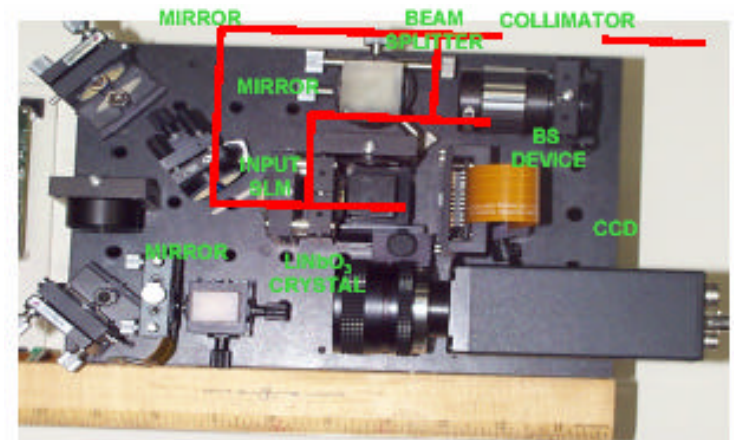


## High-Performance Onboard Computing

- Further astounding increases in processing speed
- Programmable logic and general purpose
- Eventually, radical new approaches: quantum and biological computing
- Much higher data storage densities
- Any software application possible on spacecraft



Radiation-Hardened  
High-Performance  
Processors



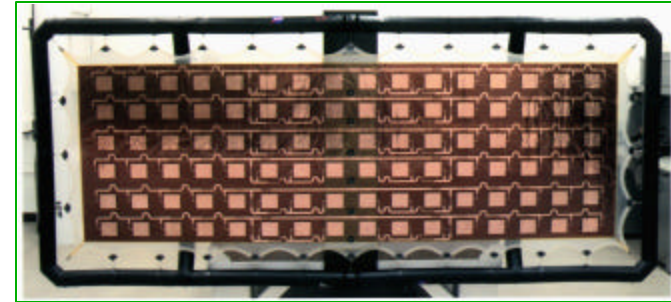
Holographic memory





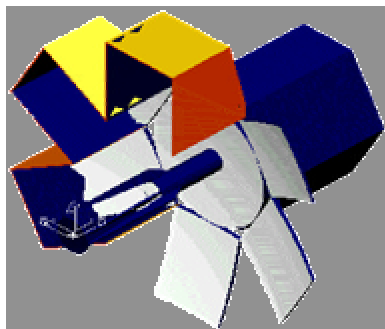
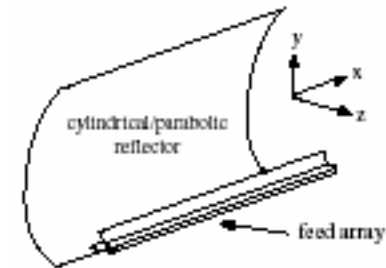
## Large, Lightweight Structures

- RF deployable mesh, synthetic aperture, and membrane antennas
- Deployable mirrors and adaptive optics
- Inflatable components

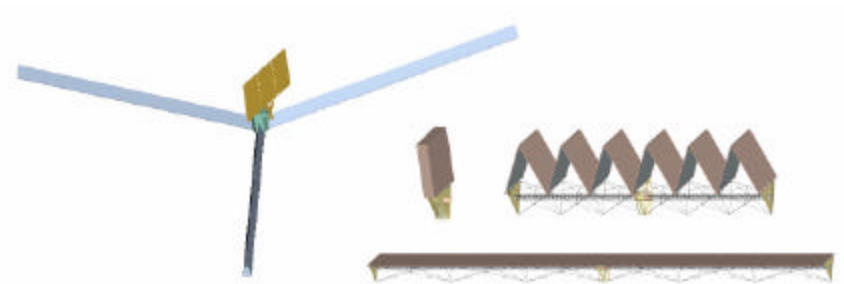


SAR Membrane Antenna

PR-2  
Antenna



Deployable Optics



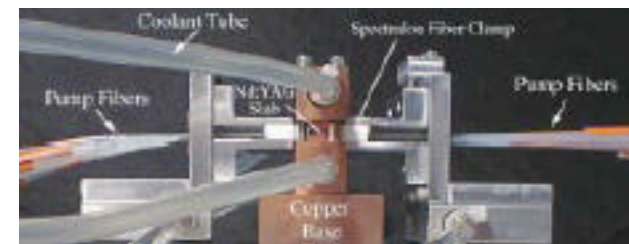
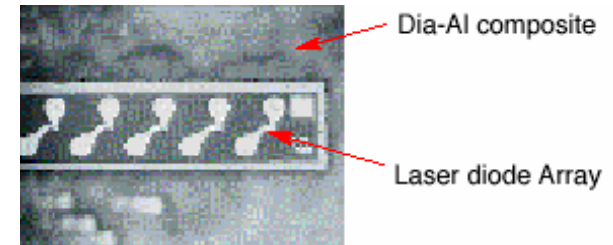
2-D Synthetic Aperture Radiometer





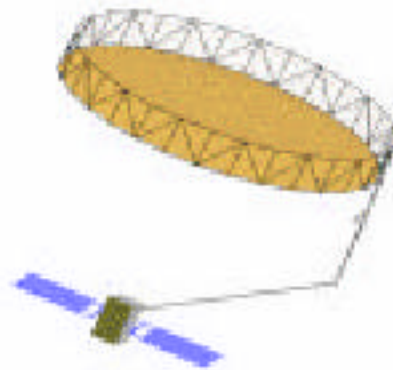
## Increased Power Active Sensing

- Increased power and efficiency for lasers and radars
- DIAL and tropospheric wind measurements from LEO
- Extension of active measurements to GEO



Edge-Pumped Laser

GEO Precipitation  
Radar Concept

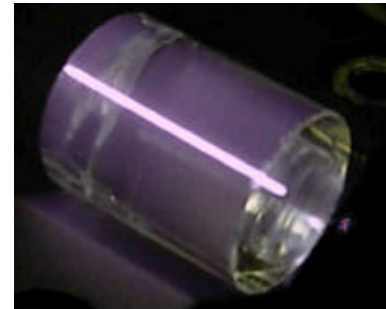


One micron  
Laser Head



## Compact Optics

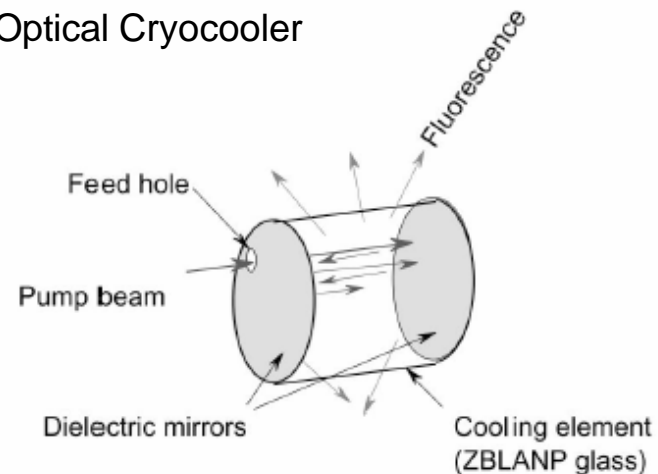
- Smaller sensors with multiple copies for greater coverage
- Innovative refractive and reflective optics
- Compact Fourier transform and grating spectrometers
- Efficient new coolers



Optical Cryocooler



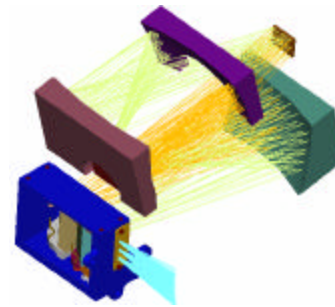
Compact Refractive IR Optics



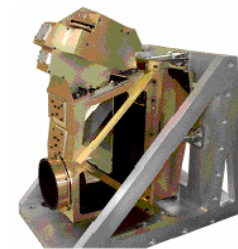


## Frequency Flexibility

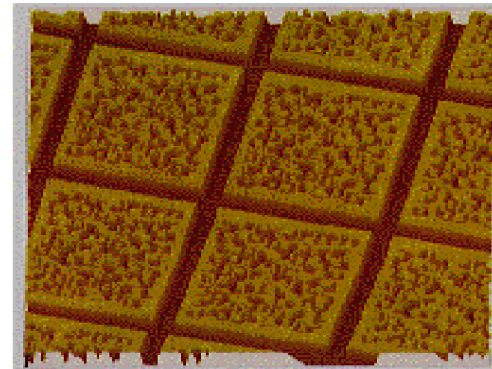
- Hyperspectral systems with on-board frequency selection, aggregation, and combination
- Tunable lasers for multiple observations with the same instrument
- Increased measurement accuracy and flexibility



High-Performance Spectroscopy



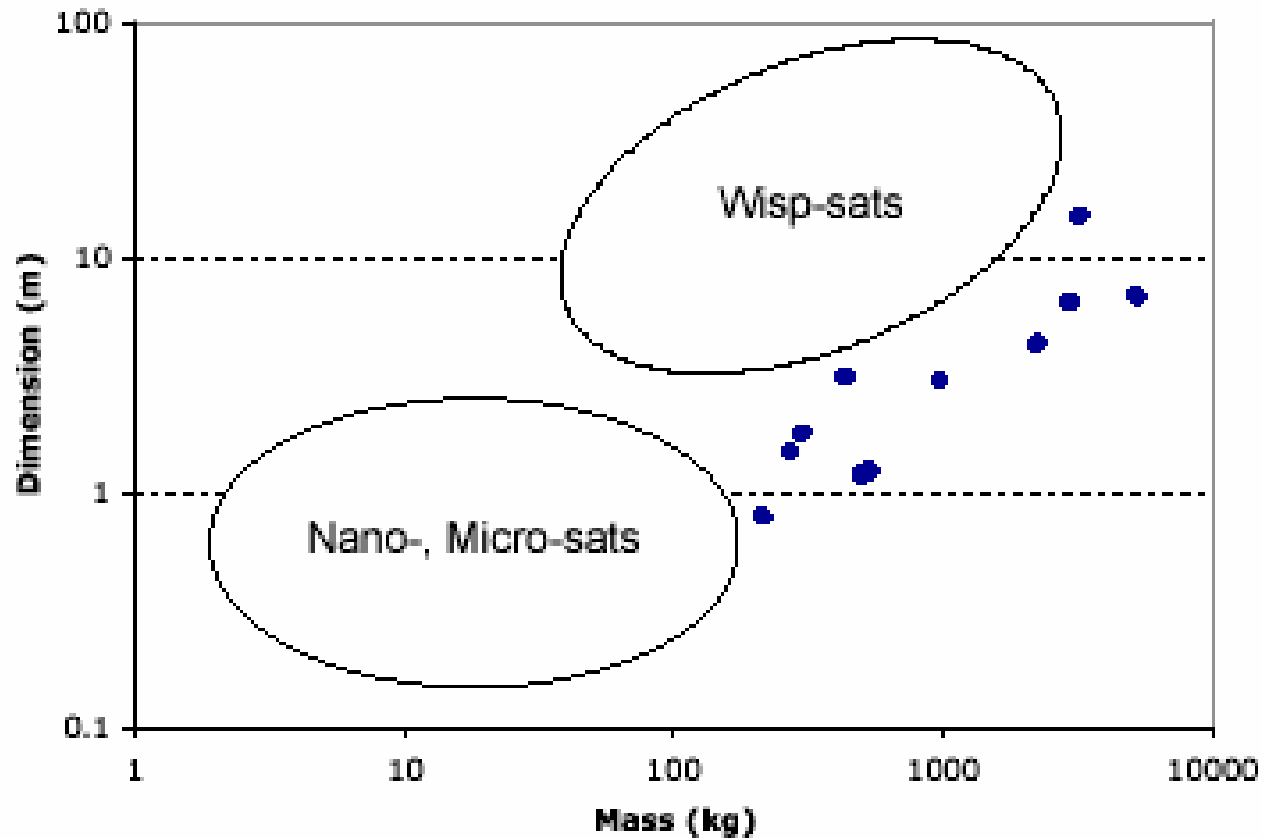
Hyperspectral Land Imaging



QWIP Pixels



## Future Sensor Spacecraft



Plotted points represent mass and largest non-solar array dimension of recent Earth remote sensing spacecraft including, ACRIMSAT, Terra, Aqua, SOURCE, TOMS-EP, ICESat, Landsat 7, GRACE, Jason-1, EO-1, and RADARSAT.



## A Bright Future

- There are many exciting challenges ahead in sensor development for Earth remote sensing.
- However, the trade space is enormous and funds are limited.
- Broad investments by the international community will enable rapid progress and support the continuing evolution of the Earth System Model.

